WA3019
10B
6/28/13

Ursus Remediation Testing & Technologies LLC
200 E Lincoln Street
Mount Horeb, WI 53572
Phone: 608.437.7413

Statement of Qualifications

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Ursus Remediation Testing & Technologies, LLC specializes in providing environmental engineers and professional's unique services in the environmental testing and remediation field.

- Ursus specializes in testing proprietary and non-proprietary chemistries at heavy metal and organic contaminated sites.
- Ursus conducts bench-level studies to determine the most effective treatment in rendering contaminants of concern non-hazardous that is cost effective.
- Ursus applies these technologies in the field by providing on-site assistance, dosage optimization, and full scale remediation.
- Ursus conducts site specific testing to model new and emerging technologies to better understand contaminant fate and transport.

Services

Ursus provides services to meet all phases of your project, from assisting in designing sampling and testing programs, conducting bench level treatability testing, performing field dosage optimization, to implementing the field remediation.

Unlike commercial laboratories, Ursus does not provide results to satisfy a regulatory commitment, but provides data to engineers, scientists, and regulators to make sound scientific and economical decisions. Ursus generates this information by applying years of analytical testing experience with, remediation investigations, and applied treatment technologies.

Bench Level Testing

Ursus uses established and innovative technologies and applies these to meet project goals. The first step is to test various technologies in a bench-level setting to determine the most effective treatment needed to achieve remediation goals. From bench-level testing, pilot and full-scale implementation can be applied.

Organics

Ursus has the expertise to evaluate a variety of treatment alternatives in a number of scenarios. Chemical oxidants and reductive dechlorination chemistries can be evaluated depending on the site geochemistry, contaminants of concern, and contaminant concentration. Data generated during an organic study is used to assist in the design for In Situ Chemical Oxidation (ISCO) remediation.

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Organic studies are conducted on soil and groundwater from the site. The materials are treated in a manner to simulate the proposed remediation approach. Varying approaches may include chemical injection, physical mixing, and batch treatment.

Metals

Ursus has the expertise to evaluate a variety of treatment chemistries to stabilize heavy metals in soil, groundwater, and wastes. Contrary to chemical vendors that test only their treatment product, Ursus does not have a proprietary treatment chemistry, therefore, we test a variety of chemistries, both proprietary and non-proprietary, to determine the most effective economical treatment approach.

Technology Evaluation

Ursus can assist you with the technology evaluation for the remediation approach. Ursus will work with you and the regulatory agency in developing an approach to meet the regulatory site requirements. Ursus has the expertise to develop a remedial plan, evaluate treatment alternatives, and assist in the field implementation.

On-site Assistance

Ursus offers on-site assistance for implementation of the remedial approach. Ursus assists client through the application of the treatment chemistry and management of the on-site treatment process. Optimizing field treatment results in significant savings by reducing the number of re-treatments, minimize chemistry overdosing, monitor chemical distribution, and utilizing field screening methodologies to reduce time and costs associated with testing.

Full scale remediation services

Full scale remediation in conjunction with on-site assistance is available. In this capacity, Ursus will conduct the chemical application, oversee treatment chemical delivery and storage, and deliver services to meet project goals and timelines.

Implementation

- Ex-situ application
  - Open excavation mixing
  - Liquid spray application
- In-situ application
  - Chemical injection
  - In-place mixing

Key Personnel

Andrew Wenzel, Principal

Andrew has over 26 years' experience in environmental testing and remediation. He has a broad range of knowledge in evaluating and applying inorganic and organic treatment strategies to contaminated sites. Andrew has treated soil, groundwater, and industrial wastes latent with heavy metals and organic wastes to render them non-hazardous. By conducting bench-level studies to evaluate varying treatment options and applying these options in the field, he has gained valuable experience in all facets of remediation. He has applied his experience ranging from small corner lot sites to superfund sites.

Andrew received his Master degree for his work in modeling the fate and transport of mercury in emergent insects and the development of a digestion method for measuring mercury in emergent insects. Andrew was issued a United States Patent for his work in removing lead from red brass faucet fixtures (US Patent 6,432,210).

Education/Certification

M.S. University of Wisconsin – Green Bay
Environmental Science

B.S. University of Wisconsin – Stevens Point
Major – Biology
Minor – Water Resources and Natural Resources

B.A. Lakeland College
Major – Computer Science

40-hour OSHA Health and Safety Training
First Aid
Adult CPR & AED

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Organic Treatability Testing Summary Table

Client	Site Location	Study Type	Contaminants of Concern	Matrix Treated	Treatment Chemistry(s)
Blaes Environmental	Arizona	Organic - Treatability Study	BTEX	Soil and GW	Alkaline Persulfate
CH2M Hill	Multiple Sites	Organic - Multiple TOD	Petroleum Hydrocarbons, Chlorinated Hydrocarbons	Soil and GW	Alkaline Persulfate, Iron Catalyzed Persuflate, Hydrogen Peroxide Catalyzed Persulfate, Oxygen Release Compounds
CH2M Hill	Multiple Sites	Organic - Multiple TOD	Chlorinated Hydrocarbons	Soil and GW	Alkaline Persulfate, Permanganate
AMEC	Duluth, MN	Organic - Treatability Study	Chlorinated Hydrocarbons, Secondary Metals Mobilization	Soil and GW	Alkaline Persulfate, Permanganate
AMEC	Multiple Sites	Organic - Treatability Study	Petroleum Hydrocarbons	Soil and GW	Alkaline Persulfate
SAIC	California	Organic - Treatability Study	Petroleum Hydrocarbons	Soil and GW	Alkaline Persulfate
SAIC	California	Organic - Treatability Study	Petroleum Hydrocarbons	Soil and GW	Peroxide Activated Persulfate
SAIC	Oakland, California	Organic - Treatability Study	Chlorinated Hydrocarbons	Soil and GW	Alkaline Persulfate, Permanganate, Fenton's Reagent
SAIC	California	Organic - Treatability Study	Petroleum Hydrocarbons	Soil and GW	Alkaline Persulfate, Fenton's Reagent
SAIC	Selfridge ANG	Organic - Treatability Study	Jet Fuel	Soil and GW	Peroxide Activated Persulfate
SAIC	Multiple Sites	Organic - Multiple TOD	Petroleum Hydrocarbons, Chlorinated Hydrocarbons	Soil and GW	Alkaline Persulfate, Iron Catalyzed Persuflate, Hydrogen Peroxide Catalyzed Persulfate, Oxygen Release Compounds
SAIC	Multiple Sites	Organic - Multiple TOD	Chlorinated Hydrocarbons	Soil and GW	Permanganate
US EPA	DAS Order Number R33663	Organic - TOD	Chlorinated Hydrocarbons	Soil and GW	Permanganate
Hull & Associates	Ohio	Organic - TOD	Chlorinated Hydrocarbons	Soil and GW	Alkaline Persulfate
Global Remediation Technologies	Michigan	Organic - TOD	Petroleum Hydrocarbons, Chlorinated Hydrocarbons	Soil and GW	Alkaline Persulfate, Sodium Percarbonate

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ORGANIC BENCH LEVEL TESTING
PROJECT EXPERIENCE

Client: AMEC Earth & Environmental, Inc.
Contact:
e-mail:
Phone:

Project:

Ursus Remediation Testing & Technologies, LLC (Ursus) provided AMEC treatability testing services at the X site in XXXXX, MN. The purpose of the study is to

1. Measure the persulfate and permanganate Total Oxidant Demand (TOD) in the test soil.
2. Conduct Effectiveness testing to measure the contaminant reduction in soil and groundwater after treatment.
3. Measure ancillary parameters in samples.

SCOPE OF SERVICES

TOD Testing

1. Prepare two soil/groundwater slurry samples.
2. Treat the soil/groundwater slurry with sodium permanganate at three dosages and measure the TOD at 48 and 96 hours post treatment.
3. Treat the soil/groundwater slurry with sodium persulfate at three dosages and measure the TOD at 48 and 96 hours post treatment.
4. Sodium persulfate will be base activated with sodium hydroxide to a pH of greater than 10. Sodium permanganate does not require activation.
5. Use information from TOD testing to set the dosage levels for Effectiveness testing.

Effectiveness Testing

1. Treat and test up to two soil/groundwater slurry samples
2. Samples will be treated with base activated sodium persulfate, iron activated sodium persulfate, and sodium permanganate at dosages levels based on data collected in TOD testing.
3. Two dosages levels will be set (low and high).
4. A control and treated samples will be allowed to react for 28 days.

5. A sacrificial sample will be prepared at the same chemistry and dosage levels to measure the ancillary parameters, including residual persulfate and permanganate, hexavalent chromium, iron, manganese, ORP, and pH. The ancillary parameters will be measured in the liquid phase of the sacrificial control and treated samples during the study, at a time to be determined, and after 28 days. Sacrificial samples will be prepared since significant volume of the liquid phase will be required for ancillary testing and exposing the samples to the atmosphere can increase the volatilization of the contaminants.

6. Water from the control and treated samples (non sacrificial sample) will be measured for VOC's at a time during the study to be determined. The soil and water fraction will be measured for VOC's at 28 days. The water fraction will be separated from the soil fraction and the respective fractions will be analyzed separately.

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Remediation Testing & Technologies LLC

Client: AMEC Earth & Environmental, Inc.
Contact:
e-mail: ____________________

Project:

Ursus Remediation Testing & Technologies, LLC (Ursus) provided AMEC Earth & Environmental, Inc., (AMEC) treatability testing services at the Xã site in Michigan.

AMEC has requested that sodium persulfate be evaluated for reduction of petroleum in site soil and groundwater.

The purpose of the study is to.

1. Evaluate potential activators for sodium persulfate.
2. Measure the persulfate Total Oxidant Demand (TOD) in the test soils.
3. Conduct Effectiveness testing to measure the contaminant reduction in soil and groundwater after treatment.
4. Measure secondary parameters in samples.

SCOPE OF SERVICES

Persulfate Activator Testing

1. Three activators are proposed for the study; iron activation, chelated iron activation, and alkaline activation.
2. Soils will be titrated to determine their acidity and alkalinity. The acidity and alkalinity data will be used to assess the activator that is most appropriate for the site. For example, if significant amounts of acid are required to achieve the optimum pH range for iron activation, then the amount of acid may be cost prohibitive or impractical to apply.
3. One activator will be chosen for TOD and Effectiveness testing.

TOD Testing

1. Prepare three soil/groundwater slurry samples.
2. Treat the soil/groundwater slurry with sodium persulfate with the chosen activator at three dosages and measure the TOD at 48 and 96 hours post treatment.
3. Use information from TOD testing to set the dosages for Effectiveness testing.

Effectiveness Testing

1. Treat and test up to three soil/groundwater slurry samples
2. Samples will be treated with activated sodium persulfate at dosages based on data collected in TOD testing.

3. Two dosages will be set (low and high).
4. A control and treated samples will be allowed to react for 28 days.
5. A sacrificial sample will be prepared at the same chemistry and dosage levels to measure the secondary parameters, including residual persulfate, total chromium, iron, manganese, lead, ORP, and pH. The secondary parameters will be measured in the liquid phase of the sacrificial control and treated samples at 14 and 28 days post treatment. Sacrificial samples will be prepared since significant volume of the liquid phase will be required for secondary testing and exposing the samples to the atmosphere can increase the volatilization of the contaminants.
6. Liquid phase from the control and treated samples (non sacrificial sample) will be measured for VOC's at 14 days post treatment. The soil and liquid fraction will be measured for VOC's at 28 days. The liquid fraction will be separated from the soil fraction and the respective fractions will be analyzed separately.

Client: Science Applications International Corporation (SAIC).
Contact: NA
e-mail: NA
Phone: NA

Project: Missouri Air National Guard Site – 139th Airlift Wing, Rosecrans Memorial Airport, ERP Site 4

Ursus Remediation Testing & Technologies, LLC (Ursus) proposes to Science Applications International Corporation (SAIC) treatability testing services for the Missouri Air National Guard Site – 139th Airlift Wing, Rosecrans Memorial Airport, ERP Site 4.

SCOPE OF SERVICES

Ursus previously conducted a Total Oxidant Demand (TOD) test on site soil using peroxide activated persulfate. SAIC has requested that peroxide activated sodium persulfate be further evaluated in a bench level treatability study. The purpose of the bench level study is to measure petroleum contaminant reduction in site soil after treatment with peroxide activated persulfate.

Samples and Baseline Testing

The same samples that had previously been tested for TOD study will be used for treatability study.

1. Approximately 250g of each sample remains. **Note:** Each sample does not express a strong petroleum odor.
2. A composite will be prepared by mixing the remaining samples.
3. The composite will be analyzed, in duplicate, for both total BTEX and TPH to measure background concentrations. The composite will be preserved with methanol at a 1:1 ratio and allowed to extract for 72 hours prior to analysis.
4. A 24 hour turn analysis will be requested for total BTEX and TPH.
5. If the composite sample does not contain petroleum constituents at a level that represents the site, then the composite may be spiked with compounds to a predetermined concentration.

Treatability Testing

1. Test one (1) composite control sample and one (1) composite sample treated sample, in duplicate, with peroxide activated persulfate.
2. The composite sample will be treated with activated sodium persulfate at a dosage based on data collected in TOD testing and discussions with SAIC.
3. Per SAIC's request, the control and treated samples will be allowed to react for 72 hours after treatment.

4. After the 72 hour treatment time, a subsample will be preserved with methanol and allowed to extract for 72 hours prior to BTEX and TPH analysis.
5. If the composite sample requires a petroleum spike, the spiked sample will analyzed for total BTEX and TPH after a 72 hour methanol extraction.
6. BTEX and TPH will be analyzed at a local commercial testing laboratory. A 24 hour turn around time will be requested.

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Influence of ISCO Catalysts, Activators, and Chelators on Secondary Metals Mobility In Soil & Groundwater

Andrew Wenzel

Ursus Remediation Testing & Technologies Services

Delivering Cost Effective, Site Specific Testing and Technology Assessments for Sound Environmental Remedial Decisions

Specialize in providing environmental consultants and contractors……

- Chemical consulting and technology assessment
- Inorganic and organic bench-level treatability studies
- Remediation oversight, technology monitoring/dosage optimization, and contracting.
- Project specific studies to evaluate new and emerging technologies.

Statement of Problem

- In-situ Chemical Oxidation (ISCO) is an established technology used to treat chlorinated and non-chlorinated organics.
- Many of the oxidants used in ISCO require activation or catalysts.
- Typical catalysts are transition metals and the metal needs to be in soluble form for effective oxidant activation to occur.
- The conditions or chemistries used to maintain beneficial environemnt for ISCO technologies are also capable of mobilizing metals from the substrate.
- This effect can cause elevated dissolved metals in monitoring wells after an ISCO application.

Activators and Catalysts

- Persulfate has the most options
  - Fe(II)
  - Chelated Fe
  - Alkaline – pH > 11
  - Peroxide
  - Heat
- Purpose – Generate Radicals
  - Radicals are Strong Oxidants
    - Sulfate Radical ($SO_4^{\bullet}$) and Hydroxyl ($OH^{\bullet}$)
    - Metal Catalysts (Fe)
      - Need to be available for the reaction to proceed
    - Alkaline Activation

Persulfate Activation

- Iron

  Fe(II)

  $2Fe^{+2} + S_2O_8^{-2} \rightarrow 2Fe^{+3} + SO_4^{\bullet} + 2SO_4^{-}2$ pH < 4

  $Fe^{+3} + 3H_2O \rightarrow Fe(OH)_3\downarrow + 3H^+$ pH > 4

  Chelated Fe (Fe-EDTA)

  $S_2O_8^{-2} + Fe^{+2}\text{-}EDTA \rightarrow SO_4^{\bullet} + SO4^{-2} + Fe^{+3+}\text{-}EDTA$ pH ≈ 7

- Alkaline

  $S_2O_8^{-2} + H_2O + OH^- \rightarrow H_2O_2 + 2SO_4^{-2} + 2H^+$ pH > 11

  $H_2O_2 \leftrightarrow HO_2^- + H^+$

  $HO_2^- + S_2O_8^{-2} \rightarrow SO_4^{\bullet} + SO_4^{-2} + O_2^{\bullet} + H^+$

  $SO_4^{\bullet} + OH^- \leftrightarrow OH^{\bullet} + SO_4^{-2}$

ISCO Conditions That Cause Metals Mobilization

- Low pH
  - Metals solubilize at low pH

    $Fe(OH)_3\downarrow + 3H^+ \rightarrow Fe^{+3} + 3H_2O$

    $PbO + 2H^+ \rightarrow Pb^{+2} + H_2O$

- Both Low and High pH (Amphoteric)

  Acid: $ZnO + 2H^+ \rightarrow Zn^{+2} + H_2O$

  Base: $ZnO + H_2O + 2OH^- \rightarrow Zn(OH)_4{}^{-2}{}_{(aq)}$

  Acid: $Al_2O_3 + 3H_2O + 6H^+ \rightarrow 2Al(H_2O)_6$

  Base: $Al_2O_3 + 3H_2O + 2OH^- \rightarrow 2Al(OH)_{4\,(aq)}$

  Acid: $PbO + 2H^+ \rightarrow Pb^{+2} + H_2O$

  Base: $PbO + H_2O + 2OH^- \rightarrow Pb(OH)_4{}^{-2}{}_{(aq)}$

- Other Amphoteric metals include Ag, Be, Cr, Co, Cu, Sb, V

ISCO Conditions That Cause Metals Mobilization

- **Chelators** are *"chemicals that form soluble, complex molecules with certain metal ions, inactivating the ions so that they cannot normally react with other elements or ions to produce precipitates or scale". (ASTM-A-380)*

$S_2O_8^{-2} + Fe^{+2}\text{-}EDTA \rightarrow SO_4^{\bullet} + SO4^{-2} + Fe^{+3+}\text{-}EDTA \quad pH \approx 7$

$ZnCl_2 + [EDTA]^{-4} \rightarrow [Zn(EDTA)]^{-2} + 2Cl^{-}$

Testing Design

Objective
- Measure the impact activate sodium persulfate has on metal mobility
  - Long Term exposure
  - Soil Attenuation

Test Sample
- Sandy soil contaminated with heavy range TPH, PAH's, and VOC's

ISCO Test Chemistry
- Sodium Persulfate

Activator/Catalyst
- Alkaline – NaOH to pH >11
- Iron – Ferrous Sulfate Heptahydrate + Sulfuric Acid to pH <4
- Iron – Fe-EDTA

Preliminary Testing
- Total Oxidant Demand (TOD)
- Soil Acidity
- Soil Alkalinity
- Total Metals

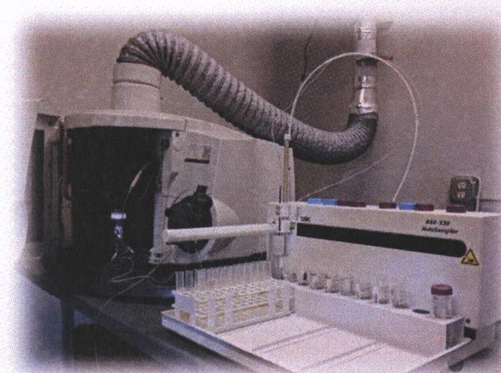
Testing Design

Long Term Exposure
- Measure dissolved metals over a one month period
- Compare persulfate treated samples to control over time

Soil Attenuation
- Expose treated pore water to untreated soil
- Repeat exposure of pore water to untreated soil
- Test dissolved metals after each exposure to measure soils ability to attenuate metals.

Metals Tested
- Al, As, Ba, Be, Cd, Cr, Cu, Co, Fe, Mn, Ni, Se, Zn

Testing Procedures
- TOD – FMC Protocols. Ursus internal methodology
- Total Metals – EPA Method 3050B and 6010B
- Dissolved Metals – EPA Method 6010B
- pH - EPA Method 9045



Baseline Data and Treatment Dosages

- Alkaline Persulfate
  - Sodium Hydroxide concentration dependent on baseline acidity and dosage of sodium persulfate added to achieve a pH above 11
  - 4.6g NaOH/kg Soil
- Iron Dosage
  - Ferrous sulfate heptahydrate added at 300 mg/kg Fe and a sulfuric acid to achieve a pH < 4
  - Fe-EDTA added at 300 mg/kg Fe

Oxidant Demand

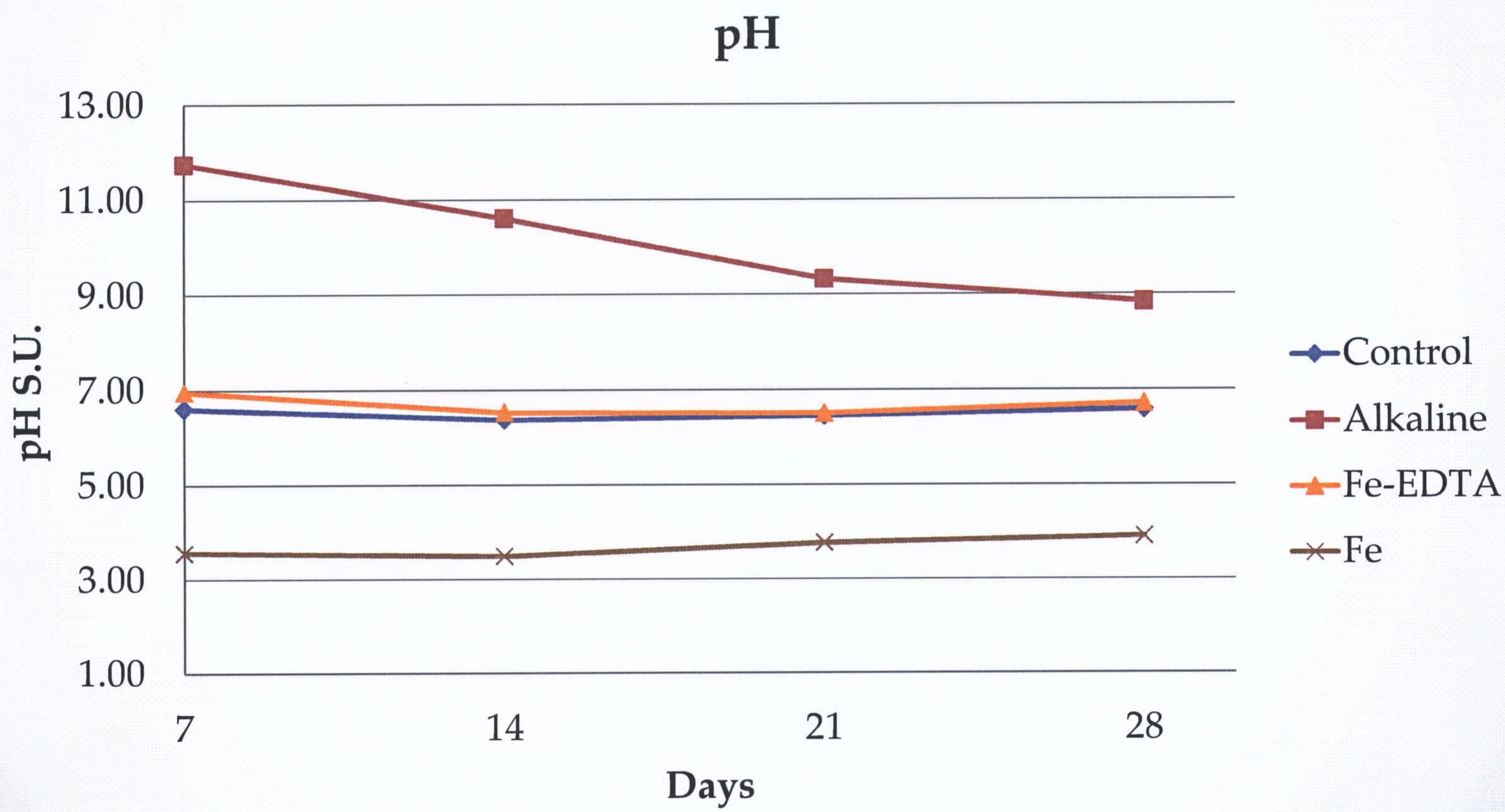
- Alkaline activated persulfate used or TOD study
- TOD measured at 48 and 96 hours post treatment
- Study found a TOD after 96 hours of 3.1 g sodium persulfate/kg soil
- A dosage of 5.0 g/kg was used in study

Total Metals

Total Metals - mg/kg dry wt.			
Al	***6,870***	**Cu**	24.6
As	BDL	**Fe**	***6,670***
Ba	8.56	**Mn**	***51.3***
Be	BDL	**Ni**	7.00
Cd	BDL	**Se**	BDL
Co	BDL	**Zn**	***776***
Cr	7.30		

BDL – Below Detection Limit

Long Term Exposure



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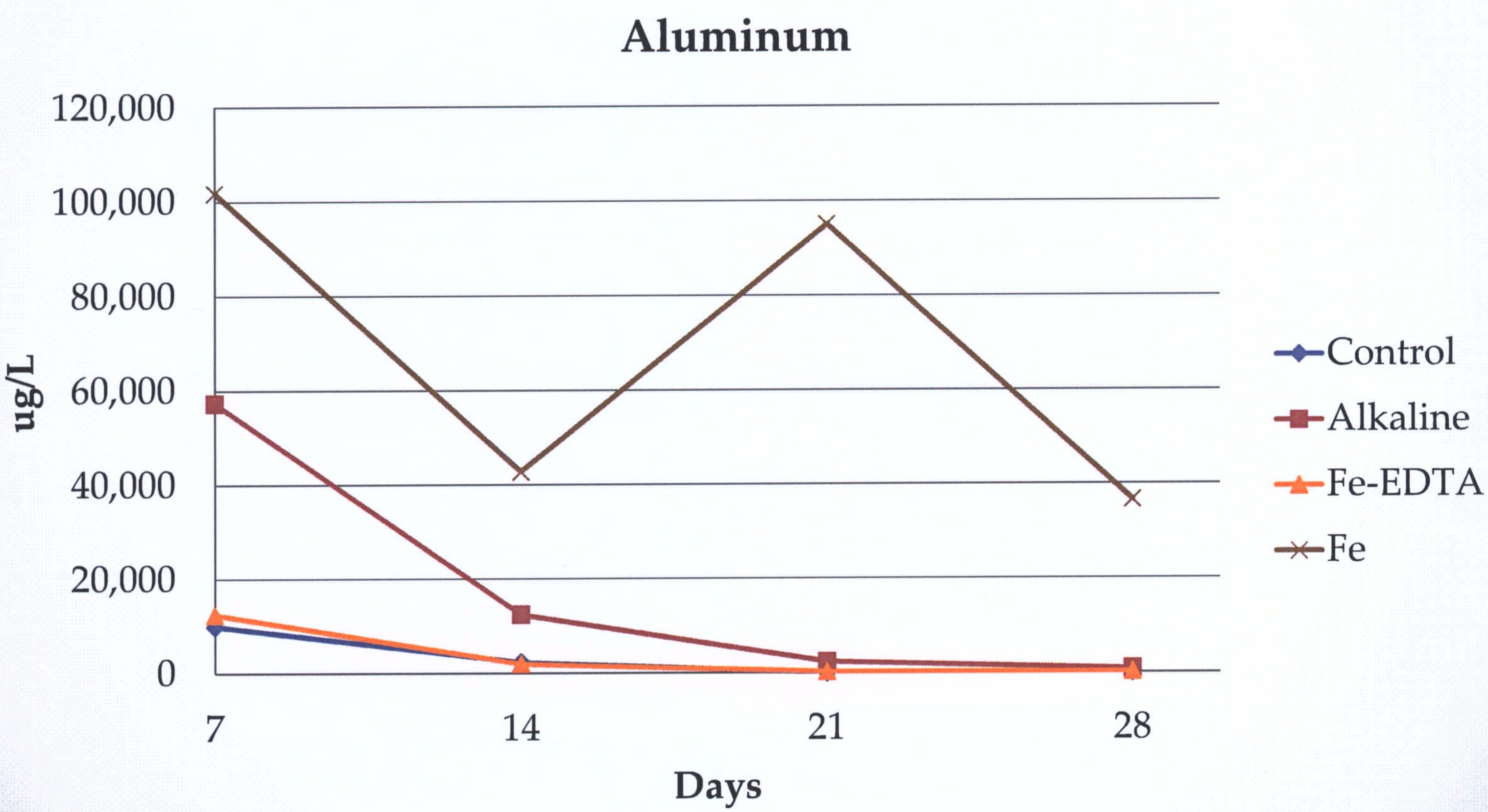

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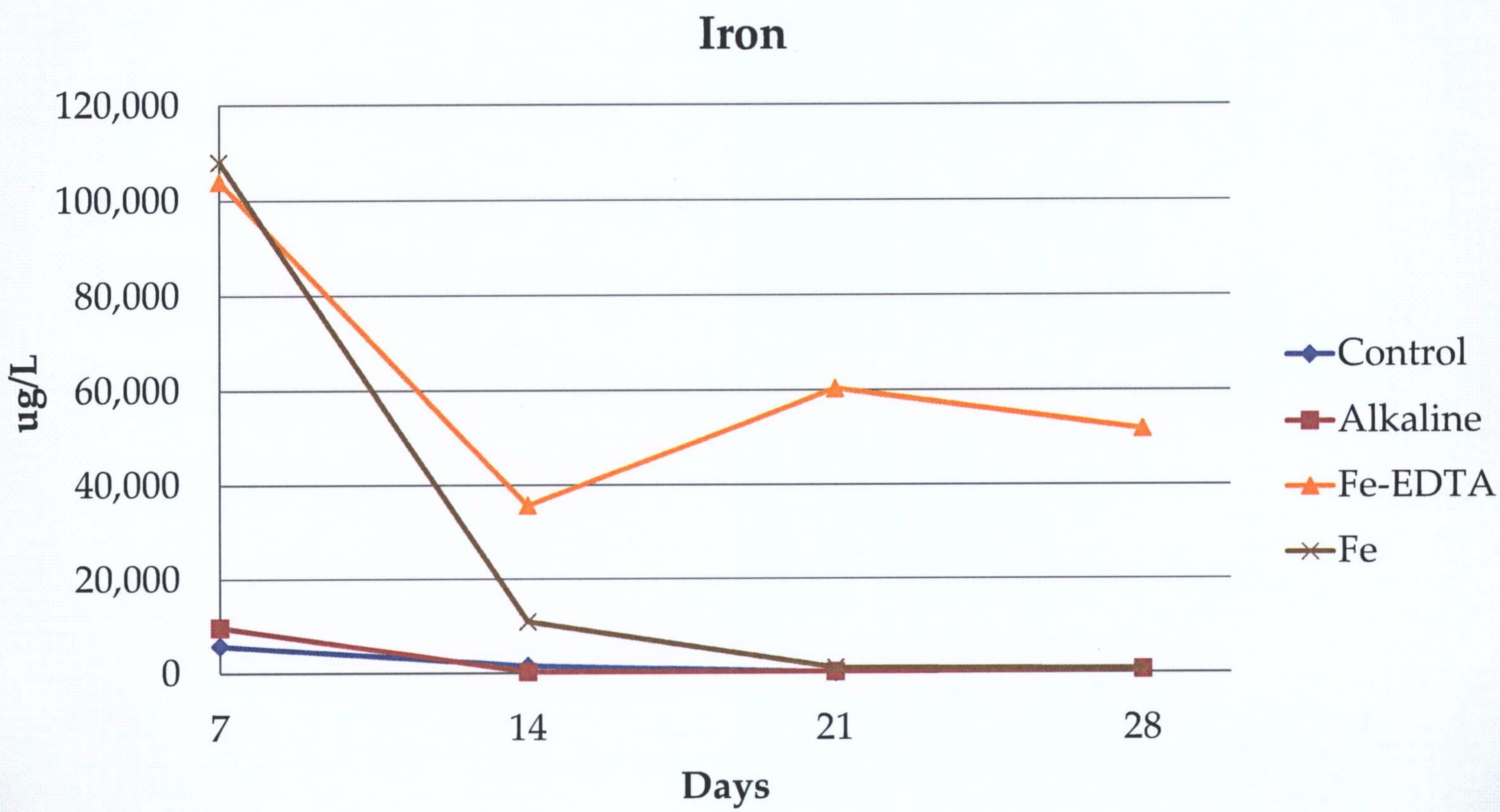

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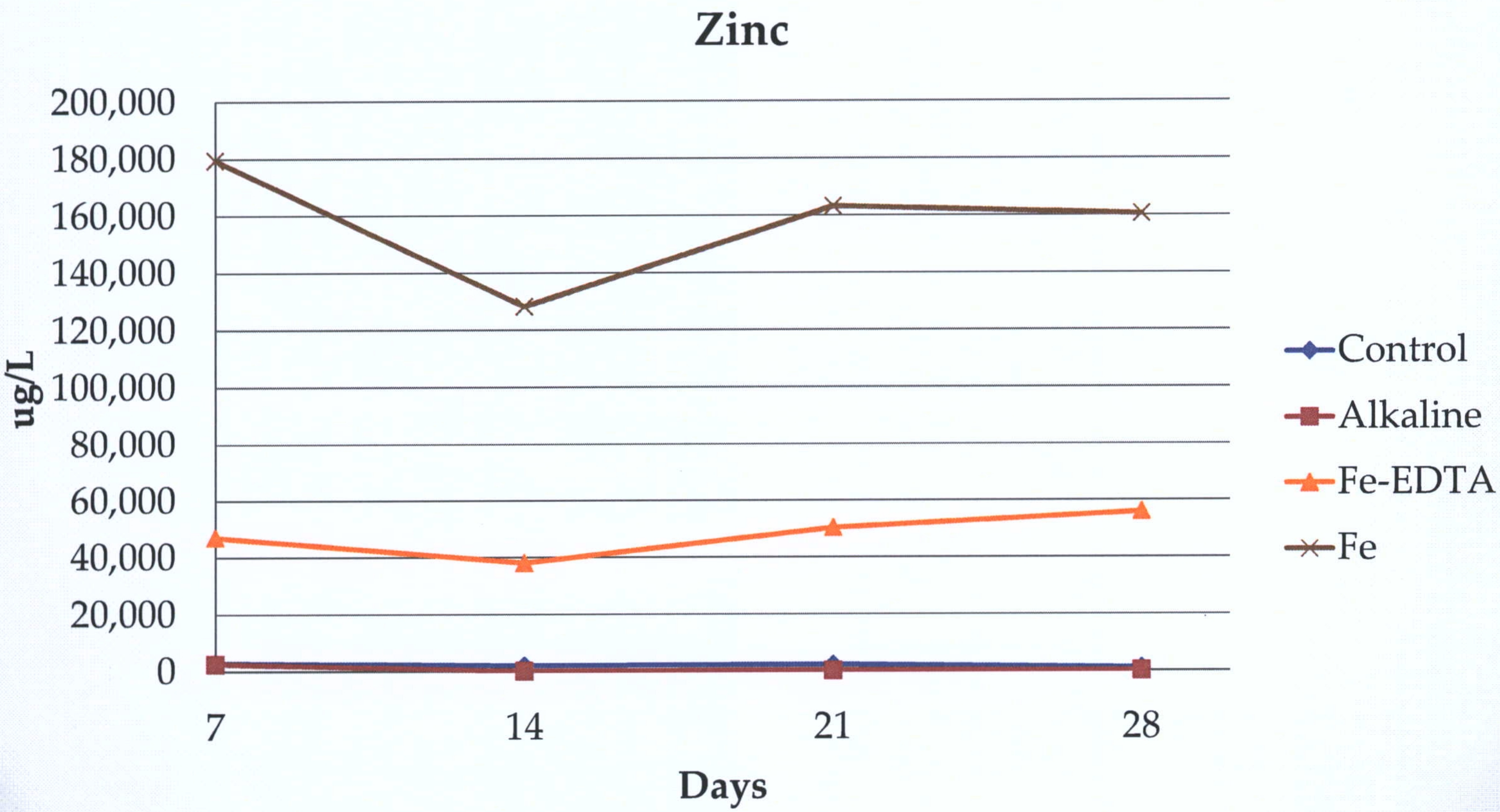

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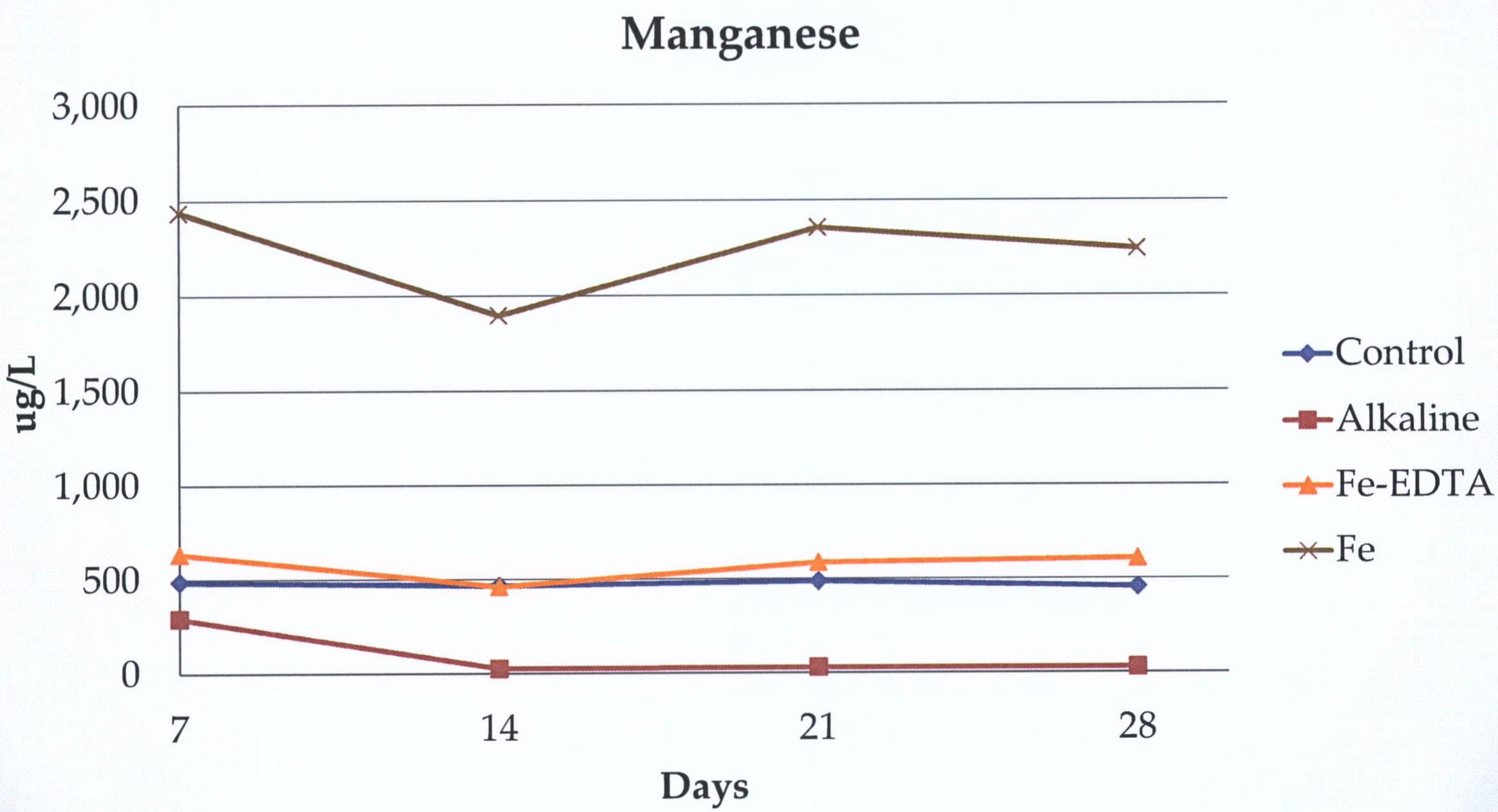
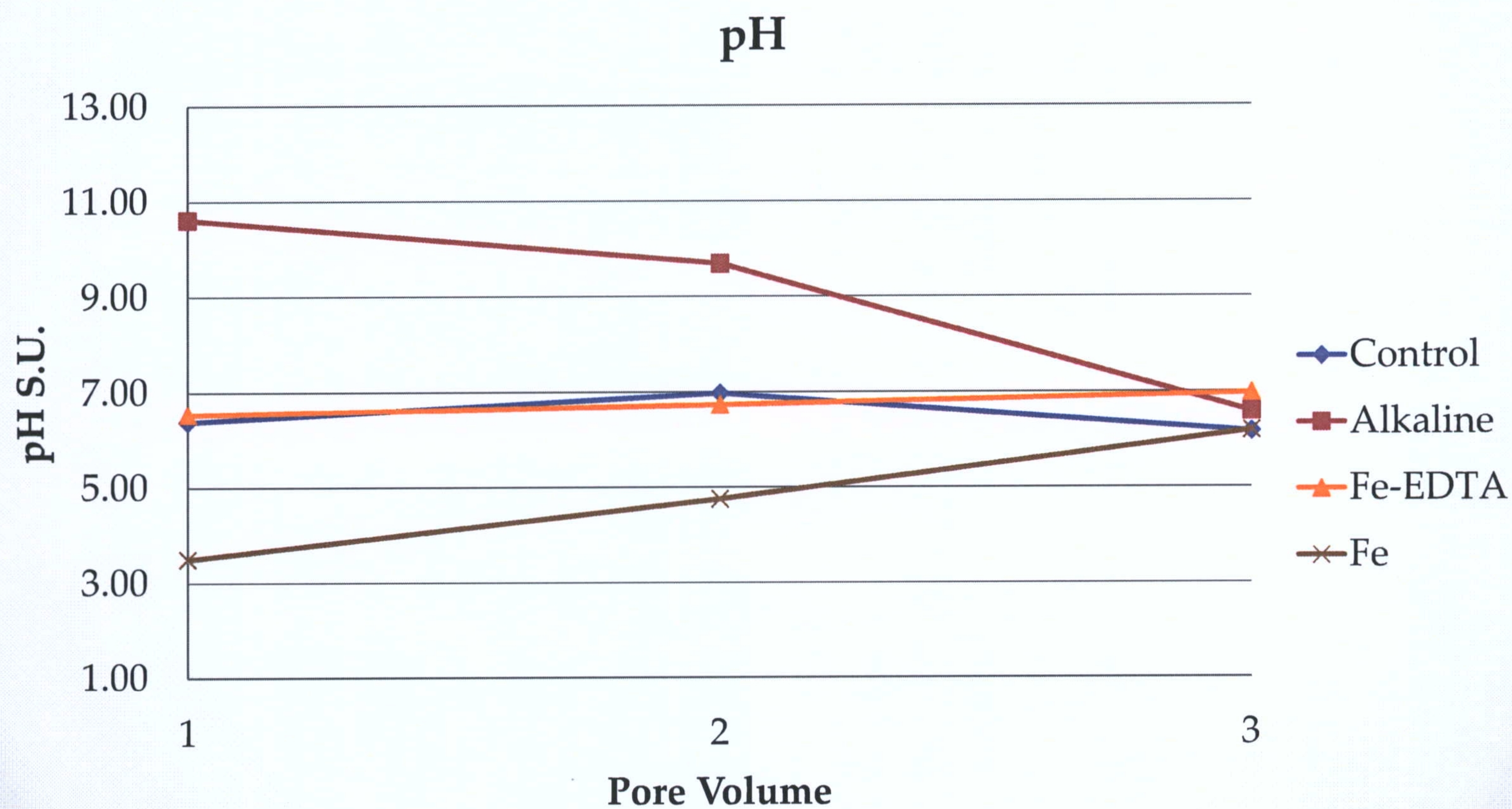


Soil Attenuation



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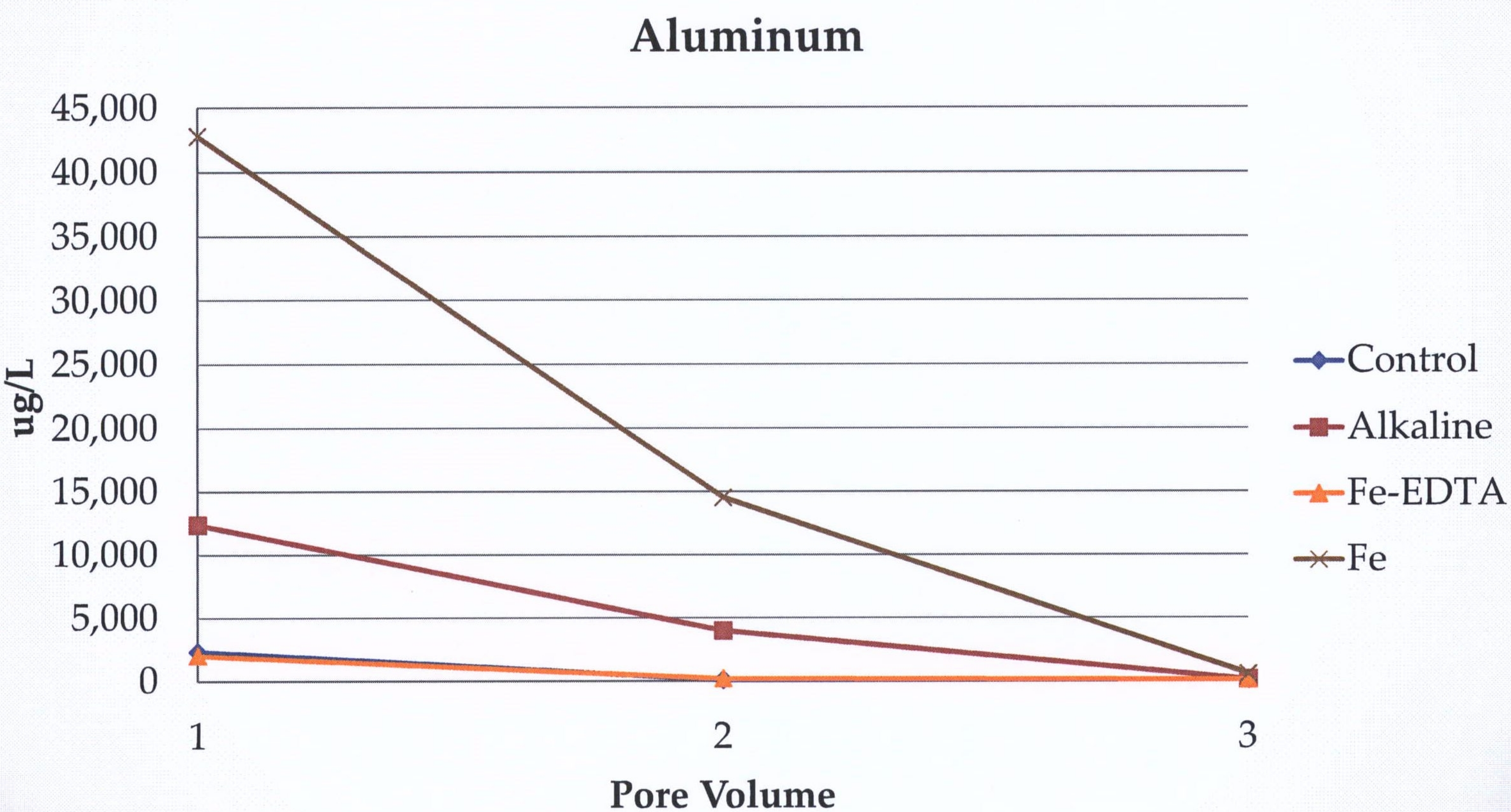

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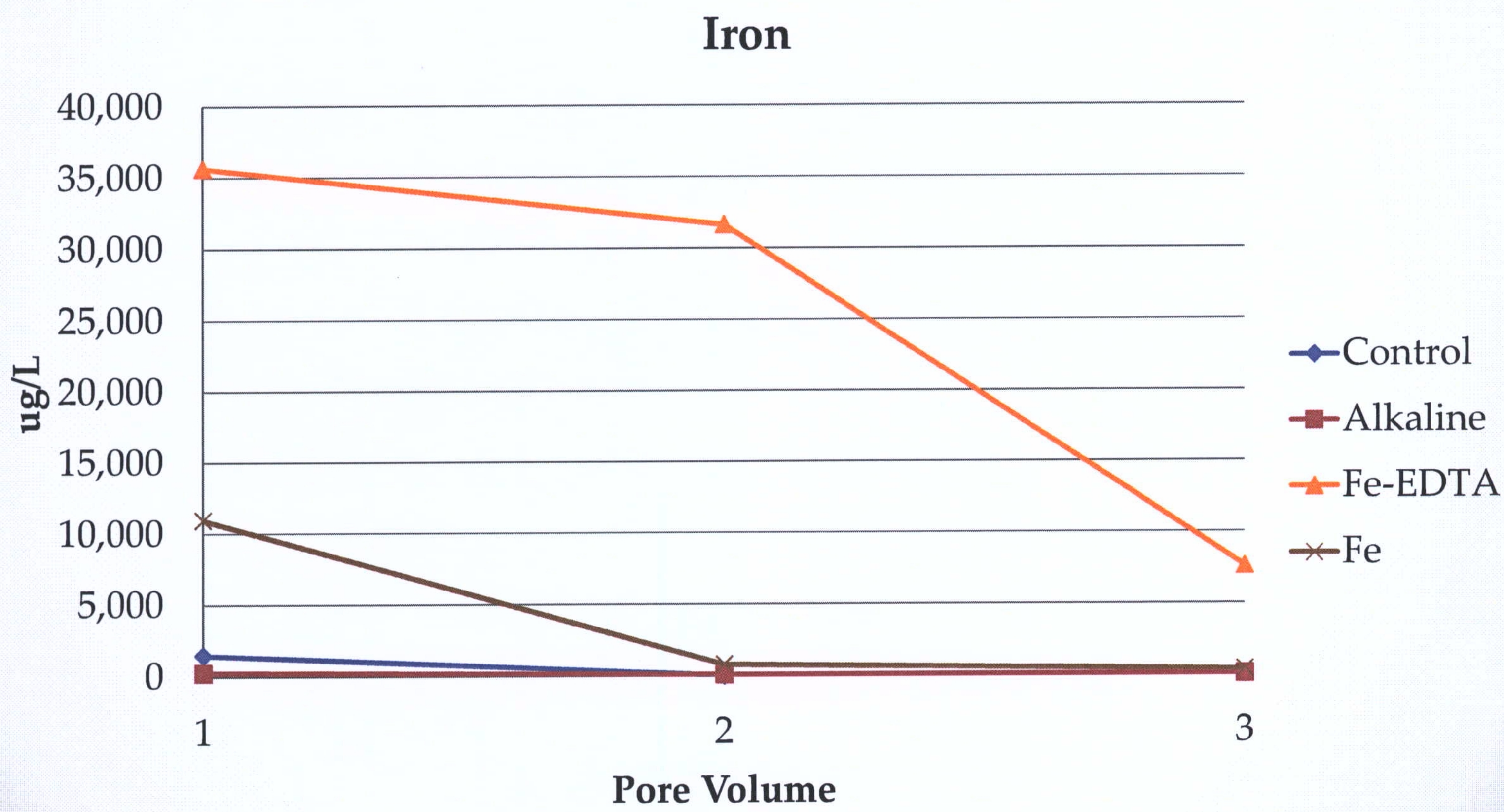

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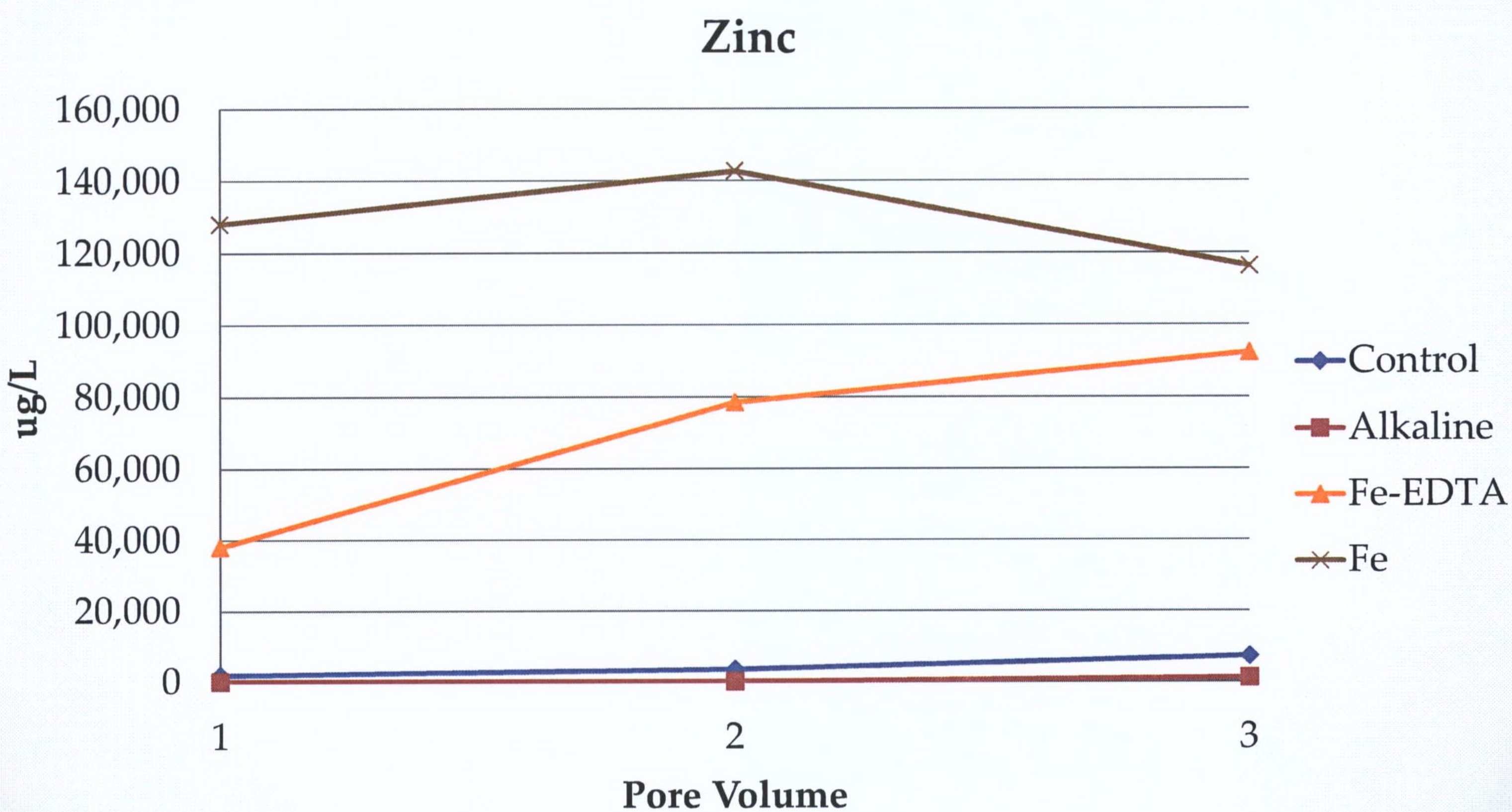
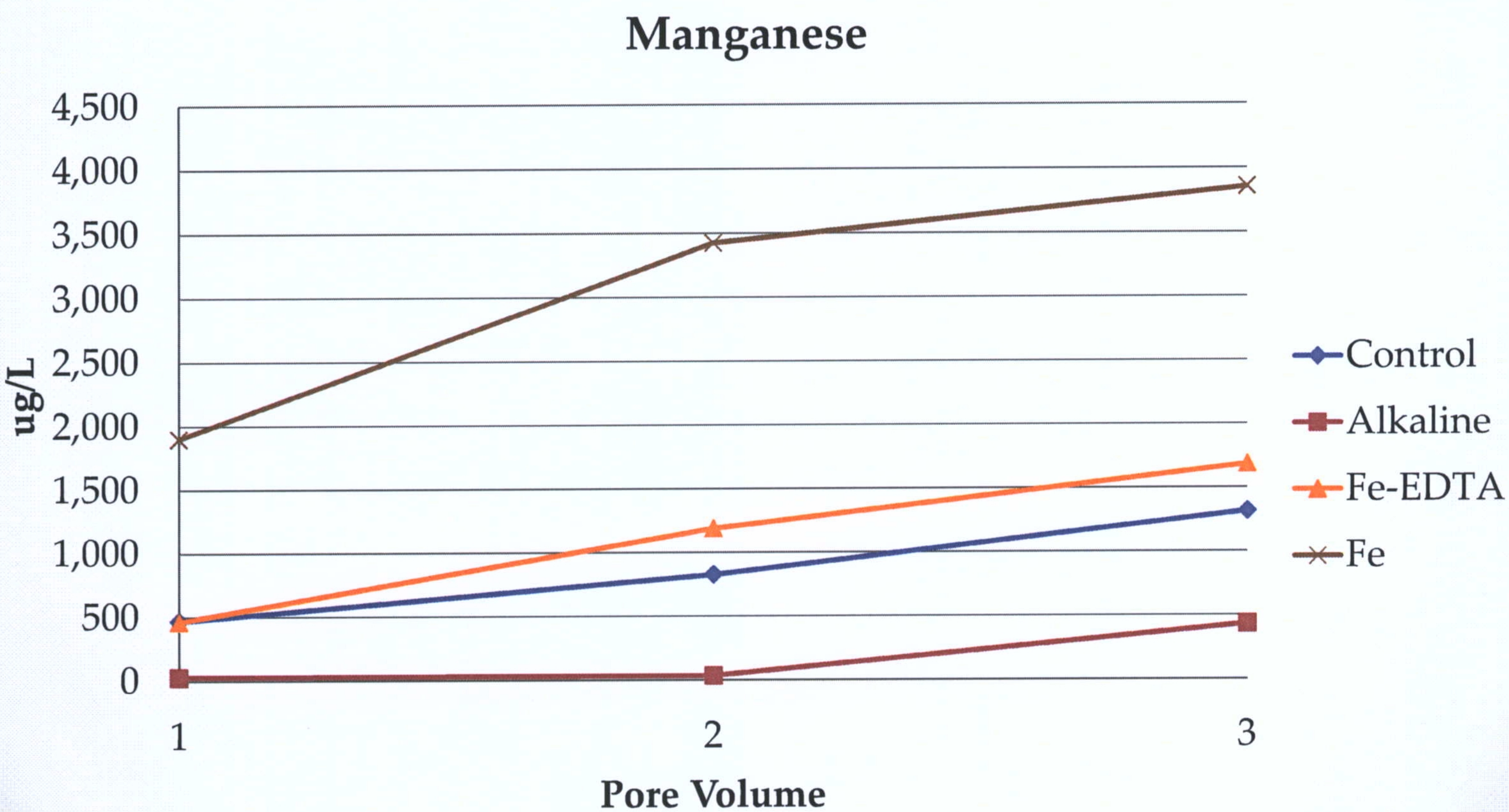


Soil Attenuation



Findings

Long Term Exposure

- Metals did not behaved equally
  - Al ↓ with Fe-EDTA. Other metals ↑
- Fe-EDTA and Fe showed higher metal concentrations than alkaline activation

Attenuation

- pH returned to neutral after 3 pore volumes
- Al and Fe showed decreasing concentrations with increasing pore volumes
- Mn increased in concentration – redox conditions

Conclusion/Recommendation

- Potential increase in groundwater metals adjacent or downgradient of ISCO implantation
- Metals released and concentration are dependent on a number of factors
  - Geochemistry of the subsurface
  - Dosage and type of activator or catalyst
  - Attenuation factors
  - Groundwater flow
  - Permanence of oxidant and catalyst/activator in subsurface
- Study shows that most metals decrease in concentration over time and with infiltration to non impacted areas

Conclusion/Recommendation

- Comingled metal and organic sites may show the highest metal mobilization
- Stable forms of metals (sulfides) maybe oxidized and mobilized during ISCO implementation
- Redox sensitive metals can be oxidized to more soluble forms - Cr(III) to Cr(VI)
- Total metals should be measured in treatment zone to measure potential metals mobility

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